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1/31/2025

ECEN 350 – LTspice Diode Characteristics Lab

(jas, LTspice Diode Characteristics Lab.docx, 1/27/2025)

Note: This is a CAD lab to be done individually, rather than in teams, although please help each other out if/when opportunities arise, while still avoiding plagiarism. Submit an electronic version of a lab report to receive credit for doing this lab. The goal of your **lab report is to provide sufficient documentation so that the lab can be repeated if necessary**. Therefore, simply add to this document to arrive at your lab report, as all of the explanatory text, procedures, and Discussion and Conclusion questions contained in this document are required for a complete lab report. So, for your lab report, **add a cover page, your results, and your answers to the Discussion and Conclusions questions to the existing lab document.** Your answers to the **Discussion and Conclusions** questions are to **be uniquely yours** and not a copy of someone else's answers to these questions. Your cover page is to include class, lab title, and author. A grading rubric for this lab is included at the end of this document. The rubric does not need to be included in your lab report.

Purpose: To become more familiar with the characteristics of standard silicon pn junction diodes along with silicon metal Schottky diodes using comprehensive diode spice models and LTspice.

Procedure:

Part 1 – Diode IV Characteristics

1. Build the circuit illustrated below in **Figure 1** in LTspice. For the 1N4007 and 1N5819, first place a standard **diode** from the main LTspice library. These diodes then need to be configured for the appropriate models. To change from the standard diode model, hover the mouse over the diode in the schematic and then right click, which opens a **Diode** pane. Then click on the **Pick New Diode** box, which opens a **Select Diode** window with many diode possibilities. For the 1N5819, it is suggested to sort on the "**type**" of diode in this window to narrow down the search and then look through the **Schottky** diode options to find the 1N5819. Selecting the 1N5819 model from the **Select Diode** window then updates the associated diode model and modifies the schematic diode symbol to the symbol for a Schottky diode. The diode type can also be changed simply by editing the value from D to 1N4007 or 1N5819 on the schematic, although this approach does not modify the schematic symbol for Schottky diodes.
   There is now an older and newer version of LTspice, with some nomenclature differences between the two versions. The older version includes a **.op** for Operating Point icon along the top toolbar, whereas the newer version uses **.t** for the same function, which opens a **Spice Directive** window. A **Spice Directive** window can also be opened by choosing **Spice Directive** in the **Edit** pull-down menu in the upper left-hand corner of the LTspice window. A **Spice Directive** window is where simulation commands are entered for inclusion on an LTspice schematic.

1. On the **Edit** pull-down menu in the upper left-hand corner, choose **Spice Analysis** which opens an **Edit Simulation Command** pane. Set the DC Sweep parameters as follows: **.dc Vs -1 1 0.001**, which sweeps the independent voltage source Vs from -1 V to 1.0 V in 1 mV increments.
2. In the **Edit** pull-down menu, add your name to your schematic as follows for the older version: **Edit → Aa Text**.
3. When completed with your schematic, replace the schematic shown in **Figure 1** below with your version, including your name. (8 points.)

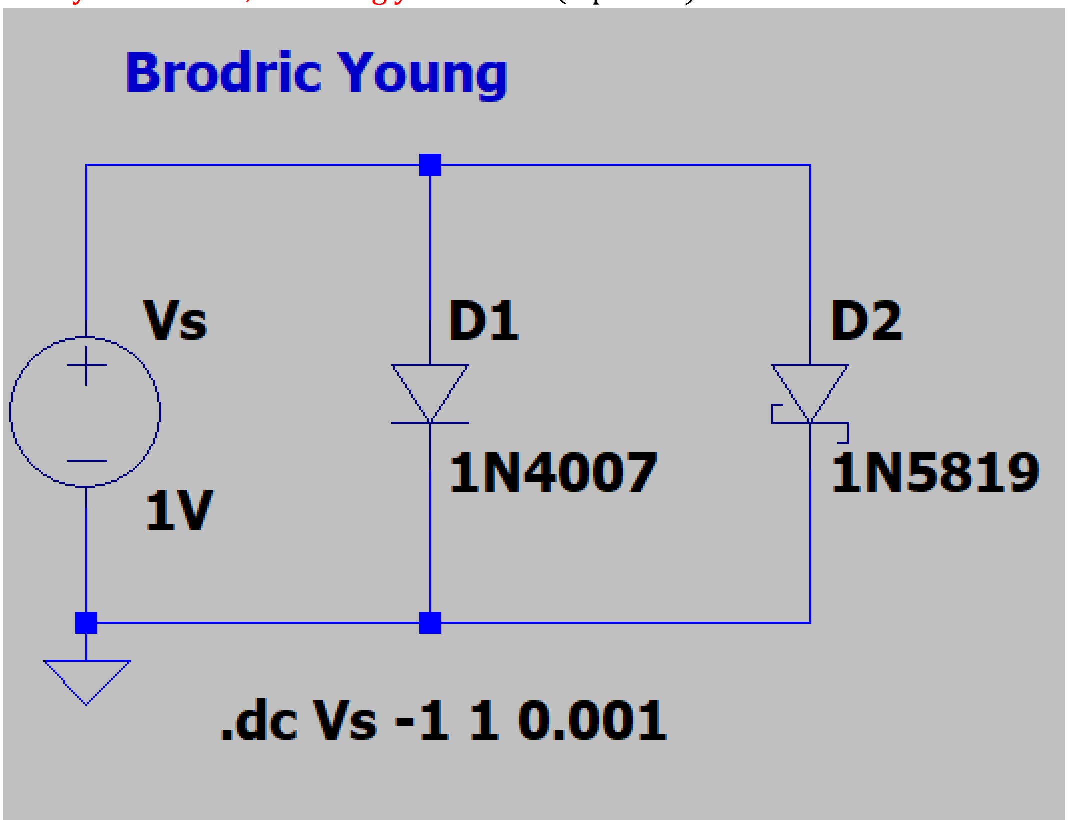

Figure 1: LTspice Circuit for Characterizing Diode Performance.

4. After running the simulation, **Click on the opened window,** go to **Plot Settings → Add trace,** and select the waveforms **I(D1)** and **I(D2)** for display.

Note: LTspice uses a dark background for the default plot pane, which makes it hard to visibly see some trace colors such as dark blue. The **Tools → Control Panel → Waveforms → Color Scheme → Background** allows you to modify the background color with Red = Green = Blue = 255 resulting in a white background. This is an optional change that you may find improves waveform viewing. If you make this change, it is also recommended to navigate to **Tools → Control Panel → Waveforms** and change the **Data Trace** and **Cursor width** from 2 to 3, along with using a Bold Font for the waveform labels so that the traces, cursors are waveform labels are more easily visualized.

5. Next limit the diode current axis in the plot pane as follows: Go to **Plot Settings → Manual Limits**, which opens a **Plot Limits** pane as shown below to be used to set the vertical axis limits at -0.1 A to 1.1 A in 0.1 A divisions.

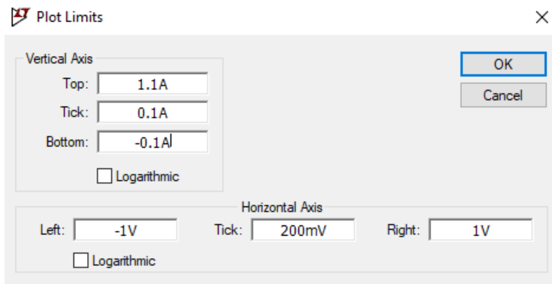

Figure 2: LTspice Plot Limits Pane.

6. Next attach one cursor to **I(D1)** and the other cursor to **I(D2).** Then adjust the **I(D1)** cursor to a voltage of 700 mV, which is a commonly used approximation for the forward bias voltage of a silicon pn junction diode. Then adjust the **I(D2)** cursor to a voltage of 300 mV, which is a commonly used approximation for the forward bias voltage of a silicon Schottky diode. Both the mouse and the left and right arrow keys can be used to move the waveform cursors along a given trace.
7. Then drag the cursor pane onto your plot to document your diode current values as illustrated in the figure below.
8. Finally, in the Plot Settings pull-down menu on the main LTspice toolbar, annotate your plot with your name as follows: **Plot Settings → Notes & Annotations → Place Text.**
9. Replace the plot pane shown in **Figure 3** below with your version, including your name, along with the cursor pane indicating diode currents. (7 points.)

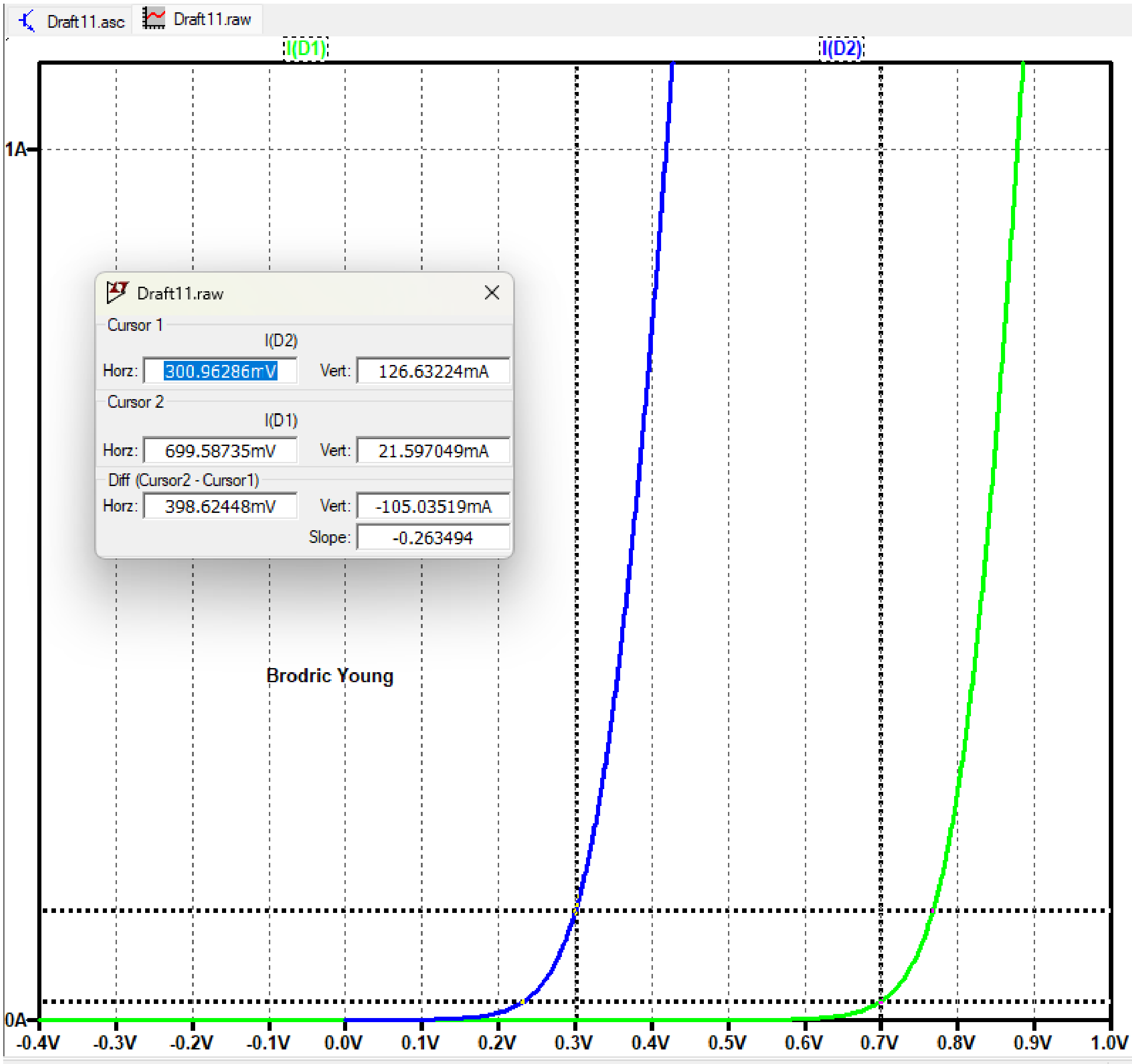

Figure 3: I-V Characteristics of a 1N4007 silicon pn junction diode and a 1N5819 Schottky Diode.

10. Using the waveform cursors and three significant figures, calculate and record below the bulk resistance of the 1N4007 occurring at $V_d = 0.75$ V for your **Figure 1** circuit. (Note: Bulk resistance is calculated as $\Delta V/\Delta I$ and is meant to approximate dV/dI at the point of interest. Hence, choose ΔV values that are slightly above and below the $V_d = 0.75$ V data point and use the associated ΔI values for your calculation.) (2 points.)

R_B = __**483 mΩ**_____.

11. Using the waveform cursors and three significant figures, calculate and record below the bulk resistance of the 1N5819 occurring at V_d = 0.3 V for your **Figure 1** circuit. (Note: Bulk resistance is calculated as $\Delta V/\Delta I$ and is meant to approximate dV/dI at the point of interest. Hence, choose ΔV values that are slightly above and below the Vd = 0.3 V data point and use the associated ΔI values for your calculation.) (2 points.)

R_B = **__337 mΩ_____.**

Part 2 – Reverse Leakage Characteristics

12. Connect up the circuit illustrated below in **Figure 4** with the voltage source Vs set to -10 V in order to reverse bias the two diodes. Note: Change the previous **.dc Vs -1 1 0.001** statement an **.op** operating point statement and add the **.step temp -55 125 5** parameter sweep statement by means of **Spice Directive**.

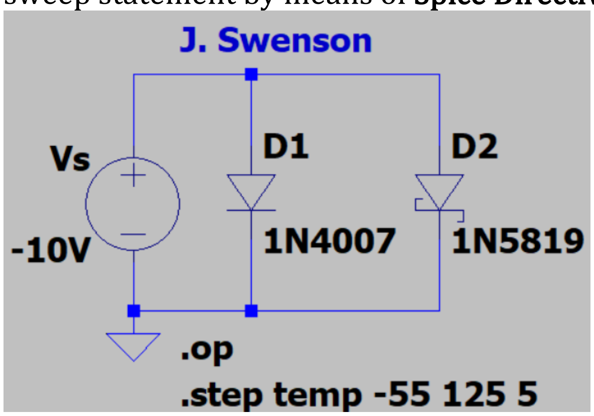

Figure 4: LTspice Diode Leakage Current Simulation Circuit.

13. After running the simulation, a Plot Pane will open in which you are to select the waveforms **I(D1)** and **I(D2)** for display. Attach one cursor to **I(D1)** and the other cursor to **I(D2)**.
14. Next with the waveform cursors, record the reverse biased diode leakage currents for each of the following temperatures listed below in **Table 1**, using three significant figures and including the sign and units. (12 points.)

Table 1: Diode Voltage and Current Values at 10 V Reverse Bias over Temperature.

Diode Temperature (°C)	I(D1)	I(D2)
-55 °C	-9.95 pA	-13.4 nA
0 °C	-13.6 pA	-4.03 μA
25 °C	-84.2 pA	-27.7 μA
70 °C	-5.67 nA	-442 μA
85 °C	-18.9 nA	-952 μA
125 °C	-312 nA	-5.71 mA

Discussion and Conclusions Questions: (For the following questions use your own words along with complete sentences. Points are to be deducted for AI generated answers.)

1. Given the I-V characteristics of the 1N4007 and 1N5819 diodes in **Figure 3**, which diode has the largest forward (static) resistance in the forward biased region? (1 point.)

    The 1N4007 has a much larger forward resistance because the voltage is much higher with the same current as the other so that results in it having a higher resistance

2. Explain why the reverse leakage current of the silicon pn junction diodes increases with increasing temperature. (Note: The reverse leakage current in Schottky diodes is larger than silicon pn junction diodes, but more difficult to explain and so not addressed in this course.) (4 points.)

    Temperature has a large effect on pn junctions because it adds energy to the electrons and creates more minority carriers that cross the junction and that creates a small amount of current. The higher the temperature, the more minority carriers and the higher the current.

3. Explain whether a silicon pn junction diode or a silicon metal Schottky diode is more like an ideal diode regarding forward voltage. (2 points.)

    For forward voltage, the silicon metal Schottky diode is more like an ideal diode because it has a lower knee voltage to overcome bec=fore conducting current. For the pn junction the knee voltage is 0.7 and for the Schottky diode its only 0.3 while an ideal diode would be basically 0. So the Schottky diode is much closer to an ideal in that area.

4. Explain whether a silicon pn junction diode or a silicon metal Schottky diode is more like an ideal diode regarding reverse leakage current. (2 points.)

    For reverse leakage current, the silicon pn junction diode is more like an ideal diode because its not affected by temperature as much as the Schottky diode because of the lower current we saw with changing temperatures. Its more like an ideal because an ideal would be like a perfect switch which would not allow reverse current at any temperature.

5. Based on your **Table 1** data, which direction does conventional current flow in a reverse biased diode, i.e., anode-to-cathode, or cathode-to-anode? (2 points.)

    For conventional current, the current would flow from the cathode to the anode because we recorded negative voltages meaning it goes in the reverse bias.

6. Explain whether a silicon pn junction diode or a Schottky diode would have a higher junction temperature for both diodes conducting the same forward current and having the same junction-to-ambient thermal resistance and ambient temperature. (2 points.)

 The diode with the higher power dissipation would have the higher junction temperature because when power is dissipated, that energy is released as heat. So the silicon pn junction diode would have a higher junction temperature because it had a higher voltage for the same current resulting in a greater power dissipation.

<u>LTspice Diode Characterization Lab Grading Rubric:</u> **This is a CAD lab to be done individually, rather than in teams, although please help each other out if/when opportunities arise, avoiding plagiarism. Submit an electronic version of a lab report to receive credit for doing this lab.** The goal of your **lab report is to provide sufficient documentation so that the lab can be repeated if necessary.** Therefore, simply add to this document to arrive at your lab report, as all of the explanatory text, procedures and Discussion and Conclusion questions contained in this document are required for a complete lab report. So, for your lab report, **add a cover page, your results, along with your answers to the Discussion and Conclusions questions to the existing lab document.** Your answers to the **Discussion and Conclusions** questions are to **be uniquely yours** and not a copy of someone else's answers to these questions. Your cover page is to include class, lab title, and author. The rubric does not need to be included in your lab report.

Lab Report Item	Points
Cover Page	2
Part 1 – Diode IV Characteristics **Figure 1**: (8 points total. 1 point for correct voltage source, 2 points for 1N4007 diode type, 2 points for 1N5819 diode type, 2 points for **.dc Vs -1 1, 0.001** statement, 1 point for name included on schematic). **Figure 3**: (7 points total – 1 point for **I(D1)** trace, 1 point for **I(D2)** trace, 1 point for -0.1A to 1.1A vertical plot limits, 1 point for cursor pane included on the plot pane, 1 point for **I(D1)** current value near to 22 mA at 0.7 V, 1 point for **I(D2)** current value near to 124 mA at 0.3 V, 1 point name included on the plot pane.) **Bulk Resistance of 1N4007**: (2 points.) **Bulk Resistance of 1N5819**: (2 points.)	19
Part 2 – Reverse Leakage Characteristics **Table 1** values with units. (12 points total - 1 point per entry, -0.25 point for each missing unit.)	12
Discussion and Conclusions	13
Grammar and Professionalism	4
Total	50

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